Power Couplers for XFEL

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Abstract

The LAL contribution to the XFEL project will be the delivery of 800 power couplers to equip 100 Cry-modules. The LAL's tasks consist on the industrial monitoring and coupler quality control at two different production sites, in addition to the RF conditioning at LAL of the 800 produced couplers. The RF conditioning and all the coupler preparation process will be held in a 70 m^2 ISO5 clean room. An RF power station delivering 5 MW, allow 8 couplers conditioning in the same time. Being in production control side and also RF conditioning one, the aim of LAL is to reach the rate of 8 couplers delivery per week, after a rump up phase. Starting of coupler mass production is scheduled for beginning 2013.

INTRODUCTION

The large experience acquired by LAL in power coupler treatment within the last ten years made it one of the key players in this field. Several studies were carried in various domains (mechanical design, RF simulation, vacuum studies, cleaning–assembling procedure and RF conditioning [1]), to better understand the RF behaviour, to improve coupler treatment procedure and to make the RF conditioning shorter and more efficient.

Historically, LAL's activities in power coupler are linked to DESY-Hamburg. Thus, several TTF3 couplers, base model of XFEL ones, were prepared and conditioned at LAL to be installed later at FLASH machine. Therefore, it is quiet normally that LAL is involved in the industrialisation and the preparation of the 800 XFEL couplers. LAL's tasks consist on the industrial monitoring at two production sites: Thales-Thonon les bains-France and Research Instruments-Cologne-Germany (RI), in addition to the RF conditioning at LAL. The first task goes from the specifications setting till the final coupler quality control. The second is held in a 70 m^2 ISO5 clean room especially constructed for this purpose. In the following, we will present some details of the coupler fabrication process in the companies and the preparation-conditioning process at LAL.

COUPLER FABRICATION PROCESS

The main steps in the coupler fabrication procedure are: the parts assemblies; The RF surfaces copper plating and TiN coated ceramic integration [2].
The two first steps are carried at Thales-Thonon production site, while the third is done at RI.

Thales-Thonon Production Site

The XFEL couplers are based on brazing technology. This well-established process at Thales-Thonon contributes to lowering coupler production coast, compared to the welding technology. Cu-Au (50-50) brazing material is used (temperature stage at 950 °C). Brazing grooves and part interface mechanical tolerances are adjusted in order to avoid centricity problem between tubular parts, gaps, edge and brazing material excess in RF surfaces.

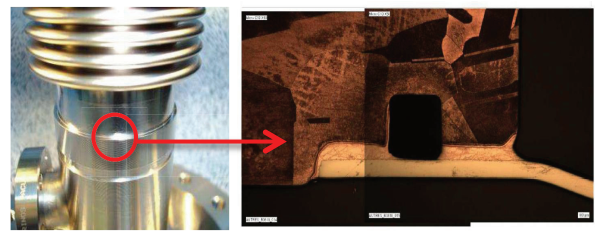

Figure 1: Cross section of a bellow-tube brazing junction.

The effect of brazing thermal cycle on bellows was also studied. An increase of the stiffness was observed in all coupler bellows, but still not binding for the coupler functioning (The actuator used for coupler tuning cover the needed force range of bellows after stiffness increase).

The copper plating is the trickiest step of the coupler fabrication process due to the part dimensions; complicate geometries of some parts (bellows, conical parts, big flanges) and mainly the very demanding specifications (10 µm ± 20% on tubular parts and ± 30% on bellows for warm and cold external parts; 30 µm ± 20% on tubular parts and ± 30% on bellows for warm internal part). To successfully overcome these constraints, a careful optimisation of the all process is needed. Special tools were designed to ensure in the same time the copper plating, the parts holding and the masking of uncoated surfaces (flanges, external surfaces of warm and cold parts, surfaces intended to EB welding).

RI-Cologne Production Site

Once the parts are assembled and coated, they are sent to RI for ceramic integrations, inner conductor and the antenna welding respectively to Warm and cold part.

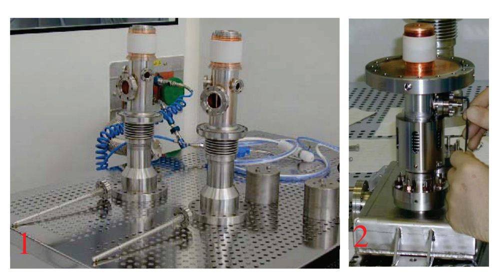

Figure 2: Warm (1) and cold (2) parts after ceramic integration and EB welding of inner and antenna.

Obtained parts are then cleaned in ISO6 clean room, dried then assembled by pair in a transition wave guide in an ISO4 clean room according to well defined procedure and with the respect of steps order:

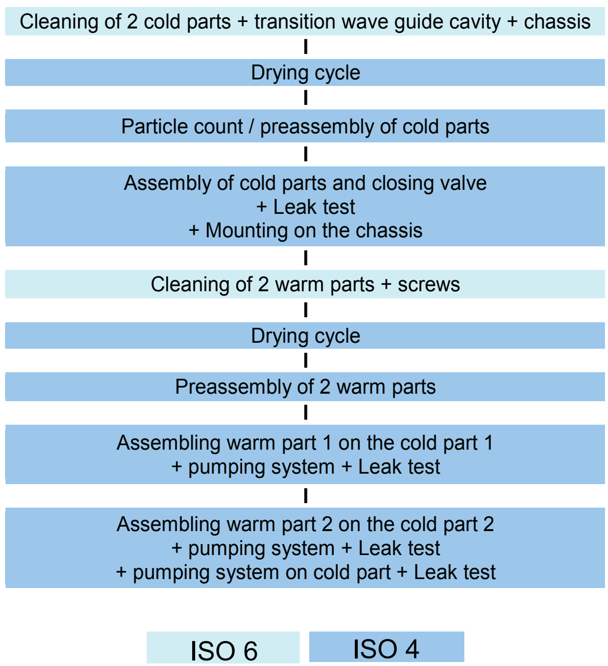

Figure 3: Coupler cleaning & assembling procedures in clean rooms.

Once these operations finished and the coupler pair tightness is validated, an RGA is mounted and a spectrum is recorded to verify the absence of hydrocarbons after cleaning. Then, a test of antenna displacement with an actuator is made to qualify the assembly. The warm parts are then filled with dried nitrogen at a pressure slightly above atmospheric one, while the two cold parts and transition waveguide box still under high vacuum. Finally, the coupler pair is double bagged in clean room, placed in a special designed shipping box and send to LAL.

COUPLER CONDITIONING AT LAL

Both processes: Coupler preparation and RF conditioning occurred in a 70 m^2 ISO5 clean room especially constructed for XFEL coupler treatment.

The clean room and the equipment installed are optimised to treat 8 couplers per week after a rump up phase.

Coupler Preparation Process

Several steps are carried out prior to RF conditioning. Upon reception at LAL, the coupler pairs are introduced in clean room and after a quick visually checked, pumping groups are mounted (getter pump, valve and gauge) in each warm part and in the set of the two cold parts and the transition waveguide box. Then, a leak test is performed. Once the tightness is verified, an in-situ under vacuum baking cycle is carried out (with a landing at 130 °C during 75 h) to remove the residual water vapour. The clean room is equipped with 3 ovens allowing the treatment of 12 couplers in the same time. At the exit of the oven, the next step is the getter pump starting and the RGA mounting. A residual gas spectrum is then recorded and compared to a coupler pair "standard spectrum". The final step, before installing the coupler pair in RF test bench, is the couplers antenna tuning in order to guaranty a good RF matching and avoid power reflection. Once all these steps are successfully performed, the coupler pair is than installed in RF test bench ready for conditioning.

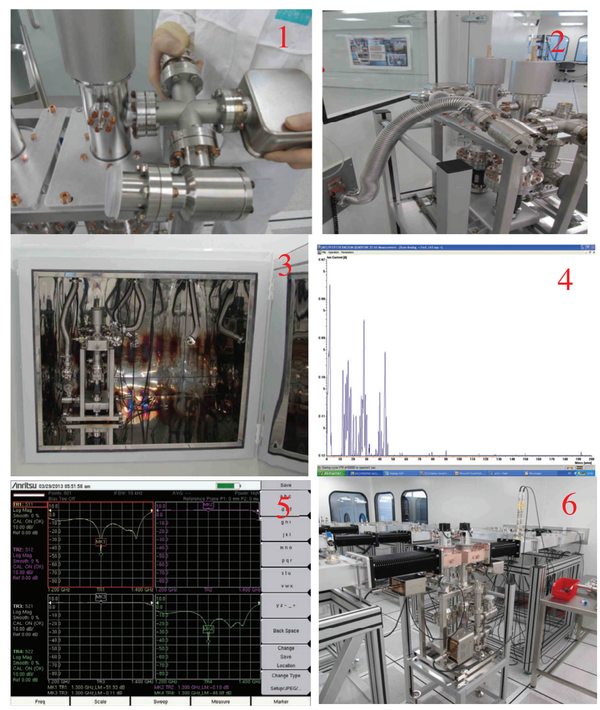

Figure 4: (1) Pumping group mounting, (2) Leak check, (3) In-situ baking, (4) RGA spectrum record, (5) Antenna tuning, (6) installation in RF test bench.

XFEL Coupler RF Conditioning

An RF power source delivering a maximum power of 5 MW was installed at LAL. A system of wave guide splitter allow to have 4 test stand with a maximum power of 1 MW each, which permit the conditioning of 8 couplers (4 pairs) simultaneously. The XFEL couplers are conditioned according to a well-established automatic procedure tested at LAL since years [1]. This procedure was adapted to the new RF test benches to manage the simultaneous conditioning of 4 pairs.

The conditioning procedure consists on the gradual rump up of the RF power at 4 Hz till reaching a maximum value, then keeping the power at this level during 1 h. These steps are repeated for several pulse lengths going increasingly. At the end of the procedure, 10 sweeps (successive increase and decrease of the power between

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minimum power and 500 kW) are performed. The figure below describes the conditioning procedure.

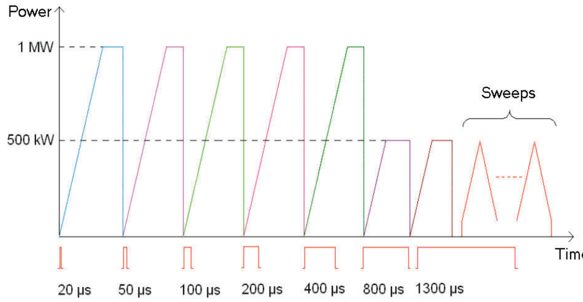

Figure 5: RF conditioning procedure description.

During the power processing, the vacuum level and the e- pick-up current in the coupler parts are monitored and kept under determined threshold by managing the power increment/decrement. Any threshold crossing triggers an interlock to avoid multipactor [3] harmful effect on coupler surfaces. Other parameters are also monitored during RF conditioning such as reflected power in coupler pair, ceramic temperature, arc detection, RF leak... all these parameters induce a hard interlock one a fixed threshold is crossed.

First XFEL couplers were successfully conditioned. Which is comforting for these new coupler design and manufacturing. In the following some results:

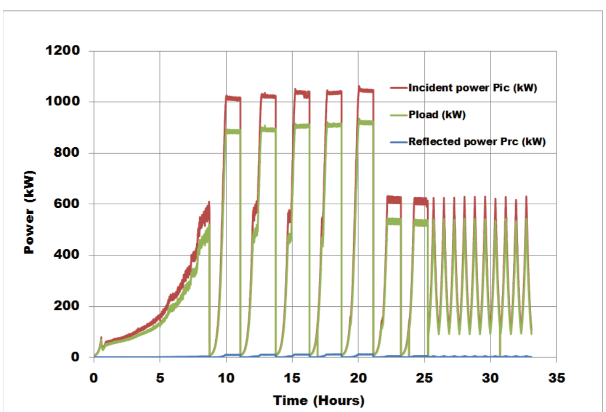

Figure 6: XFEL power coupler RF conditioning.

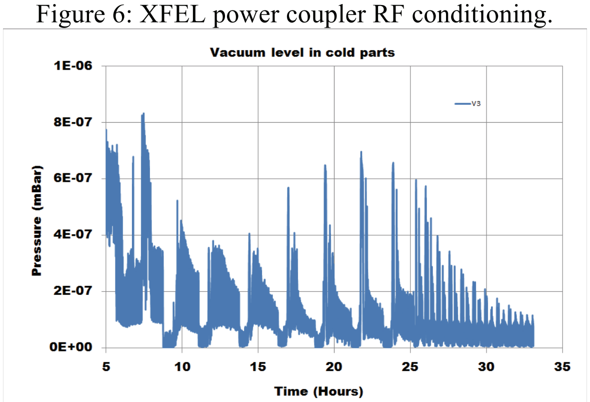

Figure 7: Pressure level measurements in cold parts during RF conditioning.

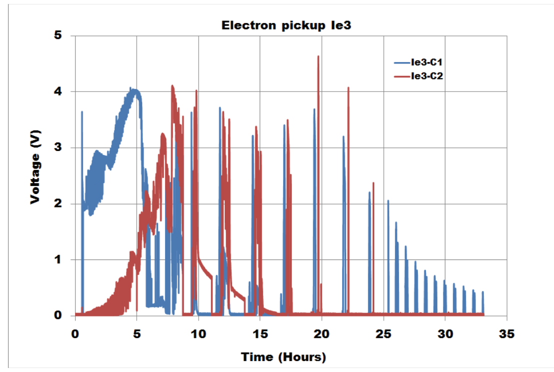

Figure 8: Electron pickup current measurement (converted to voltage: 1µA→1V) on cold parts during RF conditioning.

The global time duration of the RF conditioning procedure is nearly 33 h, which is a very reasonable duration comparable to the TTF3 coupler ones. Vacuum level and electron pickup current values in cold parts at the end of the procedure are excellent and show the success of the process.

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REFERENCES

[1] H. Jenhani, T. Garvey and A. Variola, Nuclear Inst. & Meth. In Phy. Research Sect. A (2008).
[2] J. Lokiewicz, T. Fadina, J. Kula, A. Bilinski and Z. Yu, SRF 2003, DESY, Germany.
[3] M.A.Gusarova, V.I.Kaminskii, L.V.Kravchuk, S.V.Kucaev, M.V.Lalayan, S.G.Tarasov, N.P.Sobenin XX Inter. Workshop on Charged Particle Accelerators, Ukraine, Alushta, 2007.